AD-A102 437 ILC DOVER FREDERICA DE INFLATABLE PRODUCTS DEPT F/G 13/4
DESIGN AND DEVELOPMENT OF AN ARCTIC 20,000 GALLON COLLAPSIBLE F--ETC(U)
AUG 80 C R GRAHAM, G P DURNEY DAAK70-79-C-0210

UNCLASSIFIED NL

1 of 1
AD-
A102437

END
DATE
FILMED
9-81
DTIC

3

LEVEL III

12

AD A102437

UNCLASSIFIED

DESIGN AND DEVELOPMENT OF AN ARCTIC 20,000 GALLON COLLAPSIBLE FUEL TANK (PHASE I)

Final Report for Period

1 October 1979 Through 15 August 1980

by

Curt R. Graham

George P. Durney

U.S. Army Mobility Equipment

Research and Development Command

Fort Belvoir, Virginia 22060

Prepared Under Contract DAAK70-79-C-0210 By

ILC DOVER

P.O. Box 266

Frederica, Delaware 19946

Approved for public release; distribution unlimited

UNCLASSIFIED

81 8 04 070

-15 Aug

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A102 437	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Design and Development of an Arctic 20,000 Gallon collapsible fuel storage tank, Phase I.		5. TYPE OF REPORT & PERIOD COVERED Phase I Final Report, Oct. 1979 - Aug. 1980
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Curt R./Graham, George P./Durney		8. CONTRACT OR GRANT NUMBER(s) DAAK70-79-C-0210
9. PERFORMING ORGANIZATION NAME AND ADDRESS ILC Dover, Inflatable Products Dept., Box 266, Frederica, DE 19946		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Mobility Equipment Research & Development Command, Procurement & Production Directorate, Ft. Belvoir, Va. 22060		12. REPORT DATE 15 August 1980
		13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Arctic Tanks
Fuel Storage
Elastomeric Coated Fabric
Low Temperature Flexibility

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ILC Dover has successfully developed two candidate coated fabrics for use in the 20,000 gallon Arctic Fuel Tank. The tank will have dielectrically heat-sealed seams having the strength of the fabric. Commercial hardware have been found to be acceptable for use in Phase II of this Program. ~~ILC has designed~~ a 3,000 gallon prototype tank of which two will be built of each successful candidate coated fabric.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SUMMARY

The purpose of this program was to develop coated fabrics for use in the 20,000 gallon Arctic Fuel Tank that meet the requirements of the attachments of Contract DAAK70-79-C-0210. To achieve this, two readily available base fabrics and six elastomeric coatings were chosen. From this matrix, twelve composite samples were chosen and tested. Two samples, the V84-8-1 (Estane 5708 on 8 ounce nylon) and V84-29-1 (Estane 5714 on 8 ounce nylon) did not meet all the requirements but should meet most criteria. One hundred-yard pre-production samples were made of each to insure production feasibility and further test the coated fabric. After testing, it was determined that the pre-production samples were an improvement over the laboratory samples.

It was determined that a one and one half inch overlap with a polyurethane film S-tape that is dielectrically heat sealed, would provide the tensile and peel strength and wicking protection required for seam structures.

In order to continue with Phase II of the program, handles, chafing patches, and fittings were designed. Handles exceeded the pull requirement by 780 pounds. It was determined that chafing patches could be made from the Arctic Tank base coated fabric. It was also determined that all hardware could be obtained commercially and that this hardware and a redesigned ILC suction stub should be used in Phase II.

ILC has designed a 3,000 gallon tank for the Phase II effort and recommends that two tanks of each successful fabric be built and furnished to MERADCOM for field testing and evaluation.

PREFACE

This report delineates work done under Phase I of Contract DAAK70-79-C-0210 for the U.S. Army Mobility Equipment Research and Development Command to develop coated fabrics, hardware and assembly techniques for fabrication of 3,000 gallon prototypes of 20,000 gallon fuel storage tanks capable of Arctic serviceability to -60°F. Prototype fabrication and testing is covered under Phase II of this Contract. Previous efforts by the military have resulted in acceptability at -25°F to -30°F. This report recognizes the assistance of Mr. Charles E. Mater and Reeves Brothers Research Laboratories in accomplishing the goals of this program.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

Low temperature serviceability of currently-used collapsible fuel storage tanks is limited to -25°F or -30°F. Effort was initiated by MERADCOM to extend service life to -60°F through development of suitable coated fabrics, seaming, bonding and fabrication techniques. Results of this work would then be appied to fabrication of 3,000 gallon prototype tanks for further test and evaluation.

ILC Dover was awarded contract DAAK70-79-C-0210 to accomplish the aforementioned tasks. ILC has produced two candidate coated fabrics and validated both heat sealed and adhesive seams with and without a film used to limit wicking. ILC has validated its bonding techniques to aluminum fittings and developed a leak proof suction stub. Also, a redesigned handle structure exceeds the pull requirement by 780 pounds. Results of Phase I efforts are presented in this report.

2.0 INVESTIGATION AND DISCUSSION

2.1 MATERIALS INVESTIGATION

2.1.1 Lab Sample Selection

2.1.1.1 Base Fabric Selection - The two base fabrics selected were the J.P. Stevens 8.5 ounce nylon (S/38729) and the Uniroyal 13 ounce polyester. Nylon was chosen because it is relatively low in cost and it is currently being used in fuel tank construction. Polyester was chosen because it has better dimensional stability than nylon and somewhat better resistance to sunlight, dry heat and acids.

At the beginning of this study both fabrics were available commercially and in large quantity. However, before the pre-production samples were selected, J.P. Stevens discontinued manufacture of the nylon. A back-up nylon had already been selected and was used on the pre-production samples. This fabric is the Burlington 7.87 ounce nylon (#26050). The description of the three fabrics is given in Table 1.

TABLE 1 BASE FABRIC DESCRIPTIONS

	FABRIC	COUNT	WEAVE	DENIER	WEIGHT
1.	Uniroyal Polyester	21 X 21 2 Ply Yarns Twisted 10 turn per inch	Plain	1000	13 oz/yd^2
2.	J.P. Stevens Nylon (S/38729)	31 X 31	2 X 2 Basketweave	840	8.5 oz/yd^2
3.	Burlington Nylon (#26050)	31 X 34	2 X 2 Basketweave	840	7.87 oz/yd^2

2.1.1.2 Elastomer Selection - Six elastomeric coating compounds were chosen for the laboratory sample phase. Fluorosilicone was chosen for its outstanding low temperature characteristics and its resistance to oils. Both of these characteristics are of prime importance because they are difficult to improve by blending or compounding.

Thiokol polysulfide has excellent ozone resistance and low temperature flexibility. It is also one of the most aromatic hydrocarbon fuel resistant elastomers known.

Polysulfides are, however, very difficult to process and cannot be calendered by themselves. Therefore, for this project, polysulfide was blended with neoprene for one sample and with nitrile rubber for another to increase the ease of calendering. Nitrile rubber and neoprene were chosen because they also have a resistivity to aromatic fuels. Neoprenes also have a high ozone resistance.

Polyether polyurethanes were chosen because in recent lab samples they had exhibited the capability to meet all of the requirements listed in Attachments 1 and 2 and Table 1 of Contract Number DAAK70-79-C-0210. The polyether and polycaprolactone polyurethanes have excellent low temperature properties, good tensile strength, and excellent abrasion resistance. They also exhibit good hydrolytic stability.

Polyester polyurethanes are particularly noted for fuel resistance, which is the primary reason for being considered in this project. All thermoplastic polyurethanes can be dielectrically sealed, giving a seam as strong as the material itself. This method of seaming is very reliable and offers considerable cost economies during tank fabrication.

Manufacturers were then sought who could provide one or more of the aforementioned six elastomers as a production item. Table 2 shows the commercial name and manufacturer of each elastomer. The actual formulations are shown in Appendix B.

TABLE 2 ARCTIC FUEL TANK ELASTOMER COMPOUNDS

TYPE	NAME	MANUFACTURER
Fluorosilicone	LS63U	Dow Chemicals
75%/25% Polysulfide/Nitrile	Thiokol ST/Hycar 1052	Thiokol/ B.F. Goodrich
75%/25% Polysulfide/Polychloraprene	Thiokol ST/Neoprene W	Thiokol/DuPont
Polycaprolactone, Plasticized Polyurethane	Permuthane U-24-494	Beatrice
Polyether, Polyurethane	Estane 5714	B.F. Goodrich
Polyester, Polyurethane	Estane 5708	B.F. Goodrich

2.1.1.3 Lab Sample Coated Fabric Determination - Twelve coated fabrics were selected to be used in the evaluation. These candidates are listed in Table 3.

Coated fabric samples were prepared on a laboratory coater using a knife over roller and a two zone drying oven. Samples in all cases were compounded as stated above with various proprietary primers and adhesion promoters added. In each case, an iterative method was used to determine the best primers, adhesion promoters and adhesives to use.

TABLE 3	COATED FABRIC SAMPLES
V-84-8-1	Estane 5708 polyester on 8 ounce Nylon
V-84-26-1	Estane 5714 polyether on 8 ounce Nylon
V-84-29-1	Estane 5714 (plasticized) on 8 ounce Nylon
V-84-31-1	Estane 5708 (plasticized) on 8 ounce Nylon
V-84-30-1	60/40 Estane 5714/5708 (plasticized) on 8 ounce Nylon
V-84-32-1	Caprolactone polyurethane (plasticized) on 8 ounce Nylon
2363A	75/25 polysulfide/neoprene on 13 ounce polyester
2363B	75/25 polysulfide/neoprene on 8 ounce polyester
2391A	75/25 polysulfide/nitrile on 13 ounce polyester
2361A	Fluorosilicone on 13 ounce polyester
2361B	Fluorosilicone on 8 ounce Nylon

2.1.2 Lab Sample Testing and Results

All testing done on the twelve laboratory samples was in accordance with and in the manner required by Contract DAAK70-79-C-0210. The test methods specified are listed in Tables 4, 5, 6 and 7. Due to the time required, no fungus resistance test was run on the laboratory samples. This was delayed until the pre-production samples were fabricated. It should be mentioned that similar compounds have passed this test and fungicide was added to all samples. Also, due to test fixture problems and testing time, weathering resistance tests were not run on all twelve fabrics. The tests listed in Table 7 were not run on the laboratory samples. There are many adhesives on the market which can easily meet the requirements. This testing was also delayed until the pre-production runs were fabricated.

TABLE 4 DESIRED PROPERTIES OF UNCOATED FABRIC AND CURED CANDIDATE COATED FABRIC FOR 20,000 GALLON TANK

Property	Desire Value: Uncoated Fabric	Desire Value: Coated Fabric	Test Method: ASTM	Test Method: Fed. Std. No. 191
Weave	Optional	--	--	Visual
Weight, ounces/sq. yd.,min	Record	30-40	--	5041
Thickness, mils	Record	--	--	5030.2
Fuel diffusion rate, fluid ounces fuel per square foot per 24 hours, max.	--	0.100	--	Footnote 1 & 2
Tearing Strength, lbs.				
Warp, min.	Record	35	--	5134
Fill, min.	Record	35	--	5134
Breaking Strength, lbs/in.,min.				
Warp	400	400	--	5104 (3) or 5102
Fill	400	400	--	
Accelerated Weathering - Breaking Strength Retention After Exposure At 5% Elongation for -	100 hrs.	500 hrs.		
Warp - %,min.	45	80	D-750 (4)	
Fill - %,min.	45	80	D-750 (4)	
Puncture Resistance, lb., min.	--	110	--	Footnote 5
Properties after 4 days Exposure at -60°F				
Crease Resistance Appearance After Unfolding	--	No Cracking, peeling or delaminating	--	Footnote 6
Diffusion Rate After -60°F Crease Resistance Test - fl.oz/ft²/24 hrs., max.	--	0.100	--	Footnote 2
Stiffness, max.	--	10 times stiffness at 73°F	D-3388	--
R.T. Twist	--	Record	D-3388	--
L.T. Twist	--	Record	D-3388	--
Torsion Constant of Wire Used	--	Record	D-3388	--
"G", Modulus of Rigidity @ LT, PSI	--	Record	D-3388	--

TABLE 4 continued

Property	Desired Value: Uncoated Fabric	Desired Value: Coated Fabric	Test Method: ASTM	Test Method: Fed. Std No. 191
Blocking - Separation	--	5	--	Footnote 7
Rate - seconds, max.	--			
After Soil Burial:				
Fungus Resistance	--	No cracking, blistering or delaminating of coating	--	5762
Retention of Breaking Strength - %,min.	--	50	--	5762 /5104 (3
Coating Adhesion, Original - Lb/In,Min.	--	20	D-413,Machine	Footnote 8
After Immersion in Distilled Water at 160°F 14 Days - lb/in., min.	--	10	D-413,Machine	Footnote 8
After Immersion in Test Fuel at 160°F 14 Days - lb/in., min	--	10	D-413,Machine	Footnote 1&

NOTES:

(1) Fuel composed of 70% isooctane and 30% toluene by volume. (ASTM D-471 Reference Fuel B)
(2) As per MIL-T-52573D, para. 4.6.2.9
(3) The edges of the cloth test specimen shall be coated by dipping into or brushing with a nylon solution or other adhesive or sealed by melting with heat sufficiently to preclude yarn slipping while under test.
(4) Alternate Corex D filters should be removed.
(5) As per MIL-T-52573D, para. 4.6.2.10
(6) As per MIL-T-52573D, para. 4.6.2.11
(7) As per MIL-T-52573D, para. 4.6 2.12
(8) As per MIL-T-52573D, para. 4.6 2.13

TABLE 5 DESIRED PROPERTIES OF CANDIDATE COATING COMPOUNDS FOR 20,000 GALLON FUEL TANK

PROPERTY	DESIRED VALUE	TEST METHOD ASTM	TEST METHOD FTMS 601
Initial (All Coating Compounds)			
Tensile Strength, psi (min)	1500	D-412	--
Elongation - % (min)	250	D-412	--
100% modulus psi	Record	D-412	--
200% modulus psi	Record	D-412	--
Hardness - Shore A Points	Record	D-2240	--
Tear Strength, lb/in.	Record	D-624, Die C	
Properties After Immersion In Test Fluid (1) for 14 Days at 160°F (All Coating Compounds)			
Volume Change - % (max.)	40	--	6211
Tensile Strength Retained - % (2)(min.)	50	--	6211
Elongation - %	Record	--	6111
100% modulus - psi (2)	Record	--	6111
200% modulus - psi (2)	Record	--	6111
Properties After Immersion In Distilled Water at 160°F for 14 Days (All Coating Compounds)			
Volume Change - %	Record	--	6211
Tensile Strength Retained - %, (min.) (2)	50	--	6111
Elongation - %	Record	--	6111
100% modulus - psi (2)	Record	--	6111
200% modulus - psi (2)	Record	--	6111
Ozone Resistance - 7 Days At 100°F, 50 pphm O_3 and 10% Elongation (Exterior Only)	No Cracking	D-1149	--
Properties After Accelerated Weathering for 500 Hours at 10% Elongation (Exterior Compound Only)			
Tensile Strength Retained - %(min.)	65	D-750 (3)	--
Elongation - %	Record	D-750 (3)	--
Color (Black or Outermost) (10 mils of exterior)	7.5 YR 6.5	--	Footnote 4
Properties After 4 Days @ -60°F (All Coatings)			
Stiffness, (max.)	10 times Stiffness at 73°F	D-1053 (5)	--
Room Temp., Twist, Original	Record		
L.T. Twist after 4 Days at -60°F	Record	D-1053 (5)	--
Torsion Constant of Wire Used	Record	D-1053 (5)	--
"G" Modulus of Rigidity At L.T., PSI	Record	D-1053 (5)	--
Brittleness	No cracking	D-746	--
Brittleness	No cracking	C-509 Appendix	--

TABLE 5 continued

PROPERTY	DESIRED VALUE	TEST METHOD ASTM	TEST METHOD FTMS 601
Fuel Contamination (Interior Compound)			
Unwashed Existent Gum, mg/100 ml.(max.)	20	--	Footnote 6
Heptane Washed Existent Gum, mg/100 ml.(max.)	5	--	Footnote 6

NOTES:

(1) 70% isooctane and 30% toluene by volume. (ASTM D-471 Reference Fuel B)
(2) Para. 4.8.1 "Swollen Cross-Section" applicable.
(3) Alternate Corex D filters removed.
(4) Munsell Color Standards.
(5) Type B specimens.
(6) MIL-T-52573 D, para. 4.6.2.8

TABLE 6 DESIRED CHARACTERISTICS OF CURED SEAMS

PROPERTY	REQUIREMENT	FED-STD-601 AND ASTM TEST METHOD
Breaking strength (initial)	500 lb/in. (min) 2/	8311
Breaking strength after immersion in distilled water at 160°F ± 2°F for 14 days	400 lb/in., (min)	8311/6001
Breaking strength after fuel immersion in test fluid 1/ at 160°F ±2°F for 14 days	400 lb/in. (min)	8311/6001
Dead Load shear resistance under 50 lb/in. stress at 200°F for 8 hrs.	0.125 in. slippage (max)	(3)
Peel adhesion (initial)	20 lb/in. (min)	ASTM D-413, Machine Method
Peel adhesion after immersion in distilled water at 160°F ±2°F for 14 days	10 lb/in. (min)	ASTM D-413, Machine Method/6001
Peel adhesion after fuel immersion in test fluid 1/ at 160°F ± 2°F for 14 days	10 lb/in., (min)	ASTM D-413, Machine Method/6001

1/ 70% isooctane and 30% toluene by volume.

2/ All specimens must break in the coated fabric. Failure of any specimen in a seam area at any value shall constitute failure of this test.

3/ Test specimens for dead load shear resistance testing shall be 1 inch ± 0.02 inch wide (parallel to the seam) and shall extend a minimum of 3 inches on each side of the seam. One index mark shall be scribed on each side of the seam to facilitate observation and measurement of slippage. Each specimen shall be subjected to a constant (dead load) tension force of 50 pounds ± 1/2 pound at 200°F ± 2°F. After 8 hours, examine each specimen while still under tension for signs of slippage or separation. Three specimens shall be tested for each determination. Slippage, by a specimen, greater than that specified in Table 6 shall constitute failure of this test.

TABLE 7 DESIRED CHARACTERISTICS OF CURED BONDED FITTINGS

PROPERTY	DESIRED VALUE	ASTM TEST METHOD
Aluminum to coated fabric bond strength (initial)	400 lb/in.,(min)	(1) (2)
Bond strength of fitting after immersion in distilled water at 160°F ±2°F for 14 days	400 lb/in,(min)	(1) (2) (3)
Bond strength of fitting after fuel immersion in ref. Fuel D 160°F ±2°F 14 days	400 lb/in.,(min)	(1) (2) (3)
Dead load shear resistance under 50 lb/in. stress at 200°F for 8 hrs.	0.125 in. slippage (max)	(1) (4)
Peel adhesion of aluminum strip to coated fabric (initial)	20 lb/in. (min)	(5)
Peel adhesion of aluminum strip to coated fabric after immersion in distilled water at 160°F ±2°F for 14 days	10 lb/in.,(min)	(5) ASTM D-429, Method B
Peel adhesion of aluminum strip to coated fabric after immersion in Ref. Fuel D at 160°F ± 2°F for 14 days	10 lb/in., (min)	(5) ASTM D429, Method B

(1) For determination of the strength of bonded fittings, specimens shall be prepared by cutting through the aluminum flange and clinch rings so that 1-inch wedge-shaped sections are obtained from the vent fitting. The 1 inch shall be measured as a chord passing through the midpoint between the inside and outside diameters of the clinch ring for the wedge-shaped sections. If contractor's alternate fittings are specified, samples shall be cut similarly to the above description providing 1-inch specimens measured at a chord midway between the internal and external radii.

(2) The coated fabric flanges shall be fastened together in one jaw of the test machine so that the jaw will be at least 1 inch from the nearest part of the aluminum clinch rings. The aluminum flange will be secured in the other jaw of the test machine; this jaw shall clamp only the aluminum and shall not compress the embedded part of the coated fabric flanges or clinch rings. The jaws shall be separated at a rate of 1 inch per minute at 75°F ± 5°F. The average of five test specimens shall be recorded as pounds per inch of width.

(3) For determining the bond strength after fluid immersion, five test specimens shall be immersed for the appropriate durations of each test fluid. No part of the specimens shall be covered or coated during immersion.

(4) For determining the dead load shear resistance of the aluminum to fabric bond, three specimens shall be clamped and subjected to a constant (dead load) tension force of 50 pounds at 200°F ± 5°F. At the end of 8 hours, the specimens shall be examined for slippage or separation while under tension.

(5) Special test specimens, consisting of aluminum strips bonded to the candidate coated fabric shall be prepared for peel adhesion tests. The aluminum strip shall be 12 inches long (minimum) by 2 inches ± 0.05 inch wide by 1/8 inch thick and shall be of the same allowance as that used in the aluminum fitting flanges. The coated fabric shall be 12 inches long (minimum) by 1 inch ± 0.05 inch wide and shall be of the same composition (and of the same state of cure before bonding) as that used in the coated fabric flanges. The coated fabric shall be formed using identical techniques and bonding agents used to bond tank fittings and shall be cured identically (time, pressure, temperature, etc.) to the process used in bonding tank fittings. Specimens shall be tested as per ASTM D429, Method B. Two specimens shall be averaged for each fluid immersion test. The same identical specimens shall be used to determine the initial peel strength and the strength after fluid immersion and when computing the percentage of initial adhesion retained.

The results of these tests are presented in Tables 8, 9, 10, and 11. It should be noted that the letters in the margin (I, R, and A) stand for ILC, Reeves and the U.S. Army and their corresponding lines represent test results from those sources. Reeves did most of the testing on the elastomers and the finished coated fabric. ILC generated the data on the finished coated fabric and most of the seam data. Gehman and fuel extraction data were furnished by the Material Technology Laboratory, MERADCOM. Ozone data and the D-746 brittleness test were run by the B.F. Goodrich Development Center, Avon Lake, Ohio.

TABLE 8. PROPERTIES OF CANDIDATE COATING COMPOUNDS FOR 20,000 GALLON FUEL TANK

	INITIAL PROPERTIES						PROPERTIES AFTER IMMERSION IN REFERENCE FUEL B					
	Tensile Strength P.S.I.	Elongation (Min)	100 Modulus P.S.I.	200% Modulus P.S.I.	Hardness Shore A Points	Tear Strength lbs/inc.	Volume Change % Max.	Tensile Strength Retained % Min.	Elongation %	100% Modulus PSI	200% Modulus PSI	Ozone Resistance
1. Fluorosilicone Dow Chemicals [illegible]	1130	250	430	900	65	116	1	49	80	N.T.	N.T.	No Cracking
2. 75/25 Polysulfide/Nitrile Thiokol ST/[illegible]	1040	434	320	540	54	72	12	30	290	35	39	Few Cracks
3. 75/25 Polysulfide/Polychloroprene Thiokol ST/Neoprene W	657	307	218	425	57	73	4.4	61	208	84	90	No Cracks
4. Polycaprolactone Beatrice Permuthane V-34-491	4146	865	804	1019	N.T.	444	20	44	691	71	72	No Cracks
5. Polyether Polyurethane B.F. Goodrich Estane 5713	7628	911	720	934	N.T.	474	15.7	31	745	60	66	No Cracks
6. Plasticized Polyether Polyurethane B.F. Goodrich Estane 5714	4325	1234	452	553	N.T.	283	9.1	68	1050	77	91	No Cracks
7. Polyester Polyurethane B.F. Goodrich Estane 5703	9431	983	761	1018	N.T.	623	18.4	43	983	71	69	No Cracks
8. Plasticized Polyester Polyurethane B.F. Goodrich Estane 5708	6453	883	N.T.	867	N.T.	397	0	62	524	N.T.	125	No Cracks
Requirement	1500 (min)	250 (min)					.40 (min)	50 (min)				NO Cracks

TABLE 8 Cont'd

	Properties After Immersion in Distilled H2O					Accelerated Weathering		Properties After 4 Days at -60°F					
	Volume	Tensile Strength Retained % min.	Elongation %	100% Modulus PSI	200% Modulus PSI	Tensile Strength Retained %	Elongation %	Stiffness Max.	R.T. Twist	L.T. Twist	Torsion Const. of Wire	"G" Modulus	Brittleness D-746
1. Fluorosilicone	4	78	180	140	97	NT (1)	NT (1)	7.4	154	81	.5	666	Pass
2. 75%/25% Polysulfide/Nitrile	9.8	32	296	35	29	NT (1)	NT (1)	9.5	164	91	.5	710	Fail
3. 75%/25% Polysulfide/Polychloroprene	18	69	85	59	NT	NT	NT	7.6	155	81	.5	746	Pass
4. Polycaprolactone	0	54	667	86	86	NT (1)	NT (1)	14.8	156	55	.5	16076	Pass
5. Polyether Polyurethane	13.4	36	797	70	73	121	405	10.23	154	66	.5	29828	Pass
6. Plasticized Polyether Polyurethane	5.0	61	940	81	108	NT (1)	NT (1)	3.6	165	135	.5	4861	Pass
7. Polyester Polyurethane	17.4	55	1008	83	82	NT (1)	NT (1)	49.3	149	16	.5	83554	Pass
8. Plasticized Polyester Polyurethane	6.0	29	435	NT	97	NT (1)	NT (1)	NT (2)	NT (2)	NT (2)	NT (2)	N.T.	Pass
Requirements		50 (min)				65 (min)							Pass

(1) NOT TESTED DUE TO MATERIAL THICKNESS

(2) NOT TESTED DUE TO LOW TENSILE AFTER IMMERSION

TABLE 8 Cont'd

	Brittleness F-509	Unwashed Existant Gum Mg/100 ml	Heptane Washed Existant Gum Mg/100 ml
1. Fluorosilicone	NT (3)	2.8	.2
2. 75/25 Polysulfide/Nitrile	NT (3)	14.0	11.2
3. 75/25 Polysulfide/Polychloroprene	NT (3)	18.6	11.4
4. Polycaprolactone	NT (3)	21.4	1
5. Polyether Polyurethane	NT	35.2	0
6. Plasticized Polyether Polyurethane	NT	32.6	0
7. Polyester Polyurethane	Pass	13.4	0
8. Plasticized Polyester	NT (3)	1.6	3.6
Requirements:	Pass	(20 max)	5 (max)

(3) DUE TO COST, ONLY ELASTOMERS LATER CHOSEN FOR PRE-PRODUCTION RUNS WERE TESTED

TABLE 9 ARCTIC TANK - UNCOATED FABRICS

	WEAVE	WEIGHT OZ/YD²	THICKNESS MILS	TEAR STRENGTH WARP LBS	TEAR STRENGTH FILL LBS	BREAKING STRENGTH ORIGINAL WARP LBS	BREAKING STRENGTH ORIGINAL FILL LBS	ACCELERATED WEATHERING AT 5% ELONG FOR 100 HRS Warp % Ret.	ACCELERATED WEATHERING AT 5% ELONG FOR 100 HRS FILL % Ret
13 oz. Polyester (Unroyal) 2 ply yarns, twisted 10 TPT 1000 Denier	21 x 21 plain	13	34	197	210	553	583	(1)	(1)
8.5 oz. Nylon Stevens S/38729 840 Denier	31 x 31 2 x 2 Basketweave	8.5	19 mil	77	62	500	460	63	55
7.87 oz. Nylon Burlington #26050	34 x 34 Basketweave	7.87	15	102	90.3	357	415	48	52
Requirement						400	400	45	45

(1) DUE TO THICKNESS OF MATERIAL, TEST WAS NOT RUN

TABLE 10   ARCTIC TANK   COATED FABRIC

					TEAR STRENGTH		BREAKING STRENGTH ORIGINAL		BREAKING STRENGTH ACCELERATED WEATHERING			LOW TEMP.	CREASE RESIST.	BLOCKING
		WT., oz/yd.	THICKNESS MILLS	Original Fuel Diffusion Rate Fl.oz/ft²/24 hrs.	WARP LBS	FILL LBS.	WARP LBS.	FILL LBS.	WARP % RET	FILL % RET.	PUNCTURE RESISTANCE, LBS.	APPEARANCE	DIFFUSION RATE,Fl.OZ. Ft²/24 HRS	SEPARATION WITH TALC
1. V84-26-1 Estane 5714	ILC	29.3	43		46.9	34.5	530	277	(1)	(1)	140			
Polyether on 8 oz.	REEVES	32.5	59	.27-.29	57	36	480	295	(1)	(1)	151	pass	.29-.30	pass
Nylon	ARM													
2. V84-8-1 Estane 5708	I	25.5	36		31.8	16.4	407	293	(1)	(1)	110			
Polyester on 8 oz.	R	29.6	35	.07	25	15	610	557			93	pass	.125	pass
Nylon	A			.1								pass	.3	
3. V84-29-1 Estane 5714	I	32.6	48		151	57	527	353			185			
Plasticized on 8 oz.	R	34.5	48	.41	68	63	535	360	58	59	135	pass	.41	pass
Nylon	A													
4. V84-31-1 Estane 5708	I	32.5			160	93	507	333	75	71	190			
Plasticized on 8 oz.	R	31.4	43	.21	116	58	436	315			135	pass		pass
Nylon	A			.211								pass	.178	
5. V84-30-1 60/40	I	33.3			126	53	535	323	(1)	(1)	190			
Estane 5714/5708	R	27.2	41	.272	149	74	493	281			116			pass
Plasticized - 8 oz.	A			.272								pass	.293	
Nylon														
6. V84-32-1 Capcolactone	I	31.9			78	44	510	357			165			
Polyurethane on 8 oz.	R	29.1	35	.20	68.3	38.2	529	341	76	56	152	pass	.23	pass
nylon	A			.361										
7. 2363A 75/25 poly-	I	36.1			232	282	530	380			125			
sulfide/neoprene of	R	48.4	56	1.0	164	172	384	369	90	91	113	pass	.98	pass
13 oz. polyester	A			.567								fail	.670	
8. 2363B 75/25 poly-	I	42.5			76	159.5	340	380			235			
sulfide/neoprene on	R	31.5	38	.741	202	286	447	398	98	95	125	pass	.845	pass
8 oz. nylon	A			.661								fail	--	
9. 2391A 75/25 poly-	I	43.3	48.5		46	52	340	365			90			
sulfide/nitrile	R	42.6	49	1.12	135	170	523	397	95	91	115	pass	1.24	pass
on 13 oz. polyester	A			.451										
10. 2391B 75/25 poly-	I	35.9	40		240	220	428	425			164			
sulfide/nitrile	R	36.7	38	.4	217	209 4	56	404	96	96	124	pass	.42	pass
on 8 oz. nylon	A			.309								fail	--	
11. 2361A Fluorosilicone	I	39.9			23	25	188	192			68			
on 13 oz. polyester	R	43.6	46	1.83	42	42	77	258	76	90	100	fail	--	pass
	A			1.14								fail	--	
12. 2361B Fluorosilicone	I A			1.23	36	31	159	348			76	fail	--	
on 8 oz. nylon	R	43.6	46	1.83	42.9	440	277	258	97	89	100	fail	--	pass
REQUIREMENTS:		30-40		.1 (max)	35 (min)	35 (min)	400 (min)	400 (min)	80 (min)	80 (min)			.1 (max)	

(

TABLE 10 ARTIC TANK - COATED FABRIC - Cont'd

		Stiffness ISR	R.T. Twist Deg.	L.T. Twist Deg.	Torsion Cont. of Wire Gr. x Degree	"G" Modulus of Rigidity	Coating Adhesion Original lb/in	Coating Adhesion Distilled H2O lb/in	Coating Adhesion Fuel B lb/in
1. V84-26-1	I R A	20.6	146	31	Yellow 5	30,696	20.2 35-18	22.8	17.5 20 - 13.5
2. V84-8-1	I R A	15.8	146	38	.5	43,150	34.5 48-54	37.5 41-50	26.7 25 - 33
3. V84-29-1	I R A	6.1	150	81	.5	5,292	30.2 38.2-31.6	27.5	51.4
4. V84-31-1	I R A	19.4	151	38	.5	23,466	15.7 18.9-19.3	27.5 39.5-22.5	23 26.1-31.5
5. V84-30-1	I R A	13.6	150	49	.5	9,206	52 31.5-39.5	33.2 33-28.3	40.6 24-37
6. V84-32.1	I R A	36.7	154	25	.5	27,905	34 37.5-35	33.2	6.6
7. 2363A	I R A	2.0	128	100	.5	3,168	20.6 (VB) 1.4-4.7	1.6	1.4
8. 2363B	I R A	2.1	159	140	.5	1,918	14.8 (VB) 1.0	.7	1.6
9. 2391A	I R A	7.5	129	46	.5	11,234	3.6 (VB) 3.6 6.6	Fail	1.0
10. 2391B	I R A	6.6	153	85	.5	9,991	(VB) 3.0	Fail	Fail
11. 2361A	I R A	4.3	145	90	.5	2,303	5.5 (VB) 2.3	3.1	Fail
12. 2361B	I-A R	3.4	162	131	.5	3,808	3.8	3.9	2.5
Requirements:		10 (max)					20 (min)	10 (min)	10 (min)

VB = VULCANIZING BAR

TABLE 11 ARCTIC TANK - COATED FABRICS - SEAMS

		Breaking Strength Seam w/o S-Tape: Initial lb/in	14 days @ 160°F: H20 lb/in	14 days @ 160°F: Fuel lb/in	Peel Adhesion: Initial lb/in	14 Days @ 160°F ± 2°: Distilled H20 lb/in	14 Days @ 160°F ± 2°: Fuel B lb/in.	Dead Load 50 lb/in 200°F 8 HR In	Breaking Strength Init. with S-Tape lb/in
1. VB4-26-1	I	433	236	266.7	20.2	22.8	17.5	passed	507
	R				35 - 18		20-3.5		1½"
2. VB4 8-1	I	423	250	250	35.3	37.5	26.7	passed	423
	R	1½"			48 - 54	41 - 50	23 - 33		1½"
3. VB4-29-1	I	493	323	402	30.2	36.5	51.4	--	460
	R	1½"			38.2-21.6				1½"
4. VB4-31-1	I	463	247	320	15.7	55.8	23	passed	346.7
	R	1½"			18.9 - 19.3	22.7-24.1	14.6-14.6		1½"
5. VB4-30-1	I	495	213	388	52	27.5	40.6	failed @	370
	R	1½"			31.5-39.5	39.5-22.5	26.1-31.5	5 3/4, 7 2/3, 8 hrs.	1½"
6. VB4-32-1	I	446	187	125	34	33.2	6.6	failed @	260
	R	1½"			37.5 - 35	33-28.3	24 - 37	1.58,2 1/3 2 3/4 hrs.	1½"
7. 2363-A	I	323	220	87	20.6	1.6	1.4	Pass	N.T.
	R	1½"			(VB)1.4-4.7				
8. 2363-B	I	340	149	83	14.8	.7	1.6	Pass	N.T.
	R	1½"			(VB) 1.0				
9. 2391A	I	294.5	98.3	98.7	3.6	Fail	1.0	Fail	N.T.
	R				(VB)3.6-6.6				
10. 2391B	I	258	111.6	95.6					
	R				(VB) 3.0	Fail	Fail	Fail	N.T.
11. 2361A	I	197.5	82.2	36.3	5.5				
	R	1½"			(VB) 2.8	3.1	Fail	Fail	N.T.
12. 2361B	I	132.5	76.3	Fail	3.3	3.9	2.5	Fail	N.T.
	R	1½"							
REQUIREMENTS		500 (min)	400 (min)	400 (min)	20 (min)	10 (min)	10 (min)	.125 in. max.	500 (min)

VB = VALCANIZING BAR
NT - NOT TESTED

2.1.3 DISCUSSION OF LABORATORY SAMPLE TEST RESULTS

The rubber compounds were evaluated by standard techniques using tensile sheets prepared by ASTM procedures. Some urethane compounds could not be prepared in this manner because they were supplied as solutions. Drying and molding them gave unsatisfactory results. Thin films were then prepared (4-5 mil) and much better data were obtained. All compounds were evaluated with fungicide, carbon black, and hydrolytic stabilizer added.

Polymer data on a plasticized caprolactone and the 60/40 polymer blend of Estane 5714/5708 were not obtained because data on the individual polymers had been obtained. Weathering of 4-5 mil films gave poor results due to the thinness of the films and properties are below specifications in most cases, for this reason.

All polyurethane laboratory samples were coated on a 31 x 31 count J.P. Stevens fabric. This fabric became obsolete and plant trials were made on a similar fabric having a 33 x 32 count. This fabric is more stable and the original fabric was borderline on breaking strength. All values are lower than actual due to cutting of the yarns. The grab breaking strength test is much better for coated fabric.

Coated samples of the polysulfide and fluorosilicone compounds were made using both the nylon fabric, and an open weave polyester fabric, chosen to promote mechanical adhesion. Unfortunately, they are such weak compounds that they crack when folded at -60°F, even though they are flexible. They also are lacking in abrasion, fuel permeability, and adhesion resistance.

The polyether and polycaprolactone polymers have very similar favorable properties. They are flexible at -60°F, but without plasticizer do not entirely meet stiffness parameters. Plasticization does improve flexibility at -60°F significantly, but also doubles the permeability rate. Ethers are known to display poorer diffusion resistance. Likewise, the plasticizer is extracted by the fuel. However, Material Technology Laboratory data indicate that the fuel diffusion rate drops rapidly as the temperature drops and is insignificant at 0° F. Also, most

aviation fuel used is JP-4 which has a low permeability compared to the test fluid. It is postulated that maximum flexibility is most important on a first use basis. The extraction and subsequent stiffening is not excessive, nor will it cause cracking at -60^{0}F.

The polyethers and polycaprolactones are noted for low temperature flexibility and hydrolysis resistance and the test data proves this. Polyester urethanes show a tendency for somewhat better fuel resistance and generally have relatively poorer hydrolysis resistance and low temperature properties. The polyether sample (V-84-29-1) fails only the permeability parameter and is quite flexible at -60^{0}F. All the polyurethane coated fabrics had adequate breaking strength in the warp direction. The fill strength, since these are square weave,should theoretically be the same as the warp values. Lower fill strengths observed were due to fact that the fill yarns were not aligned. In production, this can be remedied. Nearly all the fabrics pass the puncture resistance test, and meet the initial coating adhesion and tear strength requirements.

2.1.4 PRE-PRODUCTION SELECTION

Since diffusion rate is of prime importance, the first candidate for pre-production evaluation was the coated fabric with the lowest diffusion rate - V84-8-1 with a value of .07 fluid ounces per square foot per 24 hours. The coated fabric does not crack at -60°F and has good hydrolysis resistance. Although its tear strength is not adequate, it does meet the puncture resistance, coating adhesion, and tensile strength requirements. This gives V84-8-1 an excellent balance of properties, thus it was chosen for the pre-production run. The pre-production material might exhibit improved tear strength and low temperature stiffness resistance.

If the major requirements shown in Table 10 are taken into consideration, i.e., original and low temperature fuel diffusion rate, tear and breaking strength, puncture resistance, initial coating adhesion, adhesion after immersion, seam strength and seam strength after immersion, V84-29-1 meets more of the specification requirements than any other candidate., (9 out of 13). Disadvantages are a higher diffusion rate than the polyesters and a lower breaking strength in the fill direction. The diffusion rate could possibly be improved by adding blocking agents. The fill breaking strength, as explained before, could be improved by insuring in the pre-production run that the fill yarns are parallel. Because it met so many of the requirements and its' shortcomings could be improved, V84-29-1 was chosen to be the second pre-production material.

The two proposed coating compounds have excellent properties for the intended application. They also are unique in that they offer advantages for fabrication in comparison to other polymer systems such as nitrile or cross-linked urethane systems. The urethanes are thermoplastic, which means they are easily cemented or can be dielectrically bonded to form seams that are as strong as the material itself. This likewise makes patching and repair work a simple matter. Nitrile seams must be vulcanized and cross-linked urethanes are cemented with difficulty. The ability to fabricate has a large bearing on the final cost of the tank. Thermoplastic urethanes offer reliability and consistency because they are a totally reacted system before use.

TABLE 12 PROPERTIES OF COATING COMPOUNDS CHOSEN FOR PRE-PRODUCTION RUNS.

PROPERTY	DESIRED VALUE	V84-8-1	V84-29-1
Initial (All Coating Compounds)			
Tensile Strength, psi 9min)	1500	9431	4325
Elongation - % (min)	250	983	1234
100% modulus (psi)	Record	761	452
200% modulus (psi)	Record	1018	553
Hardness - Shore A Points	Record	NT	NT
Tear Strength, lb/in.	Record	623	283
Properties After Immersion In Fuel D for 14 Days at 160°F (All Coating Compounds)			
Volume Change - % max.	40	18.4	9.1
Tensile Strength Retained - % min.	50	43	68
Elongation - %	Record	983	1050
100% modulus - psi	Record	71	77
200% modulus - psi	Record	69	91
Properties After Immersion In Distilled Water at 160°F for 14 Days (All Coating Compounds)			
Volume Change - %	Record	17.4	5.0
Tensile Strength Retained - %, min.	50	55	61
Elongation - %	Record	1008	940
100% modulus - psi	Record	83	81
200% modulus - psi	Record	82	108
Ozone Resistance - 7 Days At 100°F, 50 pphm O_3 and 10% Elongation (Exterior Only)	No Cracking	No cracks	No cracks
Properties After Accelerated Weathering for 500 Hours at 10% Elongation (Exterior Compound Only)			
Tensile Strength Retained - % min.	65	(1)	(1)
Elongation - %	Record		
Color (Black or Outermost) (10 mils of exterior)	7.5 YR 6.5		
Properties After 4 Days @ -60°F (All Coatings)			
Stiffness, max.	10 times Stiffness at 73°F	49.3	3.6
Room Temp., Twist, Original	Record	149	165
L.T. Twist after 4 Days at -60°F	Record	16	135
Torsion Constant of Wire Used	Record	.5	.5
"G" Modulus of Rigidity, psi	Record	83554	4861
Brittleness - ASTM D-746	No cracking	Pass	Pass
Brittleness - ASTM D-509	No cracking	Pass	Pass

NT = NOT TESTED

(1) = Due to thickness, samples would not fit in jig.

TABLE 12 Con'd

PROPERTY	DESIRED VALUE	V84-8-1	V84-29-1
Fuel Contamination (Interior Coumpound)			
Unwashed Existent Gum, mg/100 ml. max	20	13.4	32.6
Heptane Washed Existent Gum, mg/100 ml. max.	5	0	0

2.1.5 PRE-PRODUCTION TESTING AND RESULTS

Tests were conducted during this phase of the program in the same manner listed in Table 5, 6, and 7. It should also be noted that fungicide was added to both pre-production coated fabrics. Base fabric testing was not repeated as nylon characteristics do not change.

Tests listed in Table 7 were run with several adhesives on the two pre-production fabrics. The best results of all pre-production testing are shown in Tables 13, 14, and 15.

2.1.6 PRE-PRODUCTION TEST DISCUSSION

The Estane 5708 on 8 ounce Nylon (V84-8-1) which initially was deficient in tear strength had noticeably improved in the pre-production run (from 32 x 16 to 73 x 57). The puncture resistance was improved from 93 pounds to 158 pounds. The breaking strength reported by ILC (407 x 293) also improved to 536 by 456.

The laboratory sample, V84-29-1 was initially lacking in fill breaking strength and had an unacceptably high fuel permeability rate. The pre-production V84-29 sample displayed improved qualities. The fill breaking strength was raised from 353 pounds to 492 pounds. The fuel permeability went from .41 to .27 $oz/ft^2/24$ hrs.

Although both samples have performed exceptionally well, they do not satisfy the desired fuel permeability rate. However, it is recommended that two prototype 3,000 gallon fuel tanks be built of each candidate for Arctic testing.

TABLE 13 ARCTIC COATED FABRIC - PREPRODUCTION RUNS

		WEIGHT OZ/YD^2	THICKNESS MILS	ORIGINAL DIFFUSION RATE FT.OZ/FT^2/24	TEAR STRENGTH WARP LB.	TEAR STRENGTH FILL LB.	BREAKING STRENGTH ORIGINAL WARP LB/IN	BREAKING STRENGTH ORIGINAL FILL LB/IN	BREAKING STRENGTH ACCELERATED WARP RET.	BREAKING STRENGTH WEATHERING FILL - RET.	PUNCTURE RESISTANCE LB.	LOW TEMP. CREASE RESIST APPEARANCE	DIFFUSION RATE FT/OZ/FT^2/24 HRS	BLOCKING SEPARATION PASS REQD
V84-5 E[illegible]ane 5708 Polyester on 8 ounce nylon	I R A	29.67 30.8	38.3 42	.26	80.7 73	53.8 57	536 467	456 368	(1)	(1)	186.7 158	Pass	.26	Pass Pass
V84-29 Estane 5714 on 8 ounce nylon	I R	28.5 28.3	38.5 40	.273	106 107	75 81	534 474	492 436	(1)	(1)	195 134	Pass	.37	Pass Pass
Desired Requirements		30 - 40		10 (max)	15 (min.)	35 (min.)	400 (min.)	400 (min.)	80 (min)	80 (min)	110 (min)	No Cracks	.10 (max.)	5 sec. (max)

		AFTER 4 DAYS AT -60°F STIFFNESS TSR	R.T. TWIST DEG.	L.T. TWIST DEG.	TORSION CONST. OF WIRE GR X CM/DEG.	L.T. "G" PSI	COATING ADHESION Original lb/in	COATING ADHESION H2O lb/in.	COATING ADHESION FUEL B lb/in.	AFTER SOIL BURIAL FUNGUS RET	AFTER SOIL BURIAL BREAKING STRENGTH % RETAINED
V84-8 ESTANE 5708 8 ounce nylon	I R A	32.7	148		.5 (yell.)	53,738	22.6 20.0	17.5 11-13.6	11 11.2-13.0	Pass	95
V84-29 Estane 5714 on 8 ounce nylon	I R A	5.6	155	96	.5 (yell)	6,717	34 19.1	25.3	25.3	Pass	98
Desired Requirements		10 (max.)					20 (min)	10 (min)	10 (min)	Pass	50% (min)

(1) DUE TO FABRIC thickness, samples would not fit in jig.

TABLE 13 [illegible] SEAM PREPRODUCTION RUNS

		BREAKING STRENGTH						DEAD LOAD 50 LB @ 200°F FOR 8 HRS		PEEL ADHESION					
			OVERLAP SEAM		OVERLAP SEAM W/S TAPE					SEAM W/O S TAPE			SEAM W/S TAPE		
		ORIGINAL LB/IN	DISTILLED H2O LB/IN	FUEL B LB/IN	ORIG. LB/IN	H2O LB/IN	FUEL B LB/IN	W/O S TAPE	WITH S TAPE	ORIGINAL LB/IN	H2O LB/IN	FUEL B LB/IN	ORIG. LB/IN	H2O LB/IN	FUEL B LB/IN
V84-9 Estane 5708 Polyester of 8 ounce Nylon - Diel. Heat Seal	I	456	473	472	472	420	390	Pass	Pass	22.6	17.5	11	22	21.7	10.3
	R									20	11 - 13.6	1.2 - 13.9			
Adhesive Seal		474	402	316	510	413	396	Pass	Pass	46.2	12.2	10.2	40	19.6	11.8
V84-29 Estane 5714 on 8 oz. Nylon, Diel. Heat Seal	I	363	308	377	443	368	260	Pass	Pass	34	25.3	8.0	53	41.3	21.1
	R							Pass	Pass						
Desired Requirements		500 (min)	400 (min)	400 (min)	500 (min)	400 (min)	400 (min)	.125 In. Max.	.125 In. Max.	20 (min)	10 (min)	10 (min)	10 (min)	10 (min)	10 (Min)

TABLE 15

BONDED FITTINGS - PRE-PRODUCTION RUNS

	BREAKING STRENGTH			PEEL ADHESION			DEAD LOAD
	ORIGINAL LB/IN	DISTILLED H_2O LB/IN	FUEL D LB/IN	ORIGINAL LB/IN	H_2O LB/IN	FUEL D LB/IN	DEAD LOAD
V84-8 Preprod. Estane 5708 Polyester on 8 ounce Nylon	475 (V201)	390	480	40 (V201)	21.2 V201	10.7 (V201)	Pass
V84-29 Preprod. Estane 5714 on 8 oz. Nylon	310	380	455	(V201) 50.8	28.1 (V201)	12.4 (V201)	Pass
Requirements	400 (min)	100 (min)	400 (min)	20 (min)	10 (min)	10 (min)	.125 In. (max)

V201 = Versilok 201

2.2 CONSTRUCTION INVESTIGATION

2.2.1 Seams - The seams listed in Table 14 were dielectrically sealed and data show that this type of seam can be as strong as the material. Although the Arctic tanks will be dielectrically sealed for the most part, the closing seams must be sealed with adhesive. A question that could then be raised is, "Will the adhesive pass the same seam requirements that are listed in Table 2?" To then establish a worst case condition, the seam tests should be run at low temperature. ILC conducted these tests at various low temperatures and the results of thise tests are shown in Table 16. The base fabric in all cases was the V84-8-1 pre-production fabric. It should be noted that all adhesive seams were put to the same tests run in Table 6. The results are listed as part of Table 14.

TABLE 16 LOW TEMPERATURE ADHESIVE SEAM PERFORMANCE

	TENSILE		PEEL	
ADHESIVE	TEMP. ^{o}C	VALUE LB/IN	TEMP. ^{o}C	VALUE LB/IN
Shore UBS UR1087	-25^{0}	537	-40^{0}	22.9
Bostick 7133	-25^{0}	530	-40^{0}	28.6
Shore UBS UR1092	-25^{0}	570	-50^{0}	21.7
B.F. Goodrich A1246B	-25^{0}	513	-50^{0}	21.2

These adhesive samples were placed in a Missimar chamber and pulled insid the chamber itself. Before data was taken, the chamber and samples were given thirty minutes to stabilize. The samples were then pulled in accordance with Federal Standard 601 Method 8311 for seam strength samples and ASTM D-413, Machine Method, for peel samples.

It was ascertained that an overlap seam with a S-Tape provided adequate wicking protection if the closing of the tape outside the seam (Figure 1) could be accomplished. In order to refine this process to make the manufacture of these seams easier, it is advantageous to use a fuel resistant polyurethane film. It was found that Tuftane 310 (made by B.F. Goodrich) not only

retained or improved the initial peel and breaking strength values but also maintained equivalent values (compared to the plain overlap seams) after immersion. These results are shown in Table 14.

2.2.2 HANDLES

The requirement for handles as stated in MIL-T-82123A, paragraph 3.5.2, is that the bonds between each handle patch assembly and the tank fabric shall be capable of withstanding a perpendicular load of 1,000 pounds. In order to meet this requirement, the ILC handle assembly was designed.

To confirm that the handle meets the requirement, an assembly was cut in half, placed in a fixture and pulled until it failed. A 10 inch diameter patch was fabricated to simulate not only equal loading around the fixture, but also a worst case condition. If the handle fails on the tank in the field, it will fail first around the 10 inch circular arc. This is because there is less bonded area in the area of the semicircle than there is towards the center of the patch.

The fixture is shown in Figure 1, and the test was run on both pre-production fabrics. Both assemblies passed this test and the V-84-8-1 material went to 1780 pounds before permanent deformation of the handle. This test is more severe than would actually occur because in the field, the load would be distributed throughout the tank. In this test, the load was distributed along a 17 inch diameter.

2.2.3 CHAFING PATCH DESIGN

It is a well known fact that high modulus polyurethanes are extremely abrasion resistant. In order to ascertain if the base fabric could be used as a chafing patch, Taber abrasion tests were run on several lab samples, including the two samples chosen for the pre-production runs.

The abrasion test was run with an H22 wheel (which simulates a gravel road) for 1000 cycles. The wheel was sanded every 100 cycles. The results of this test are shown in Table 17.

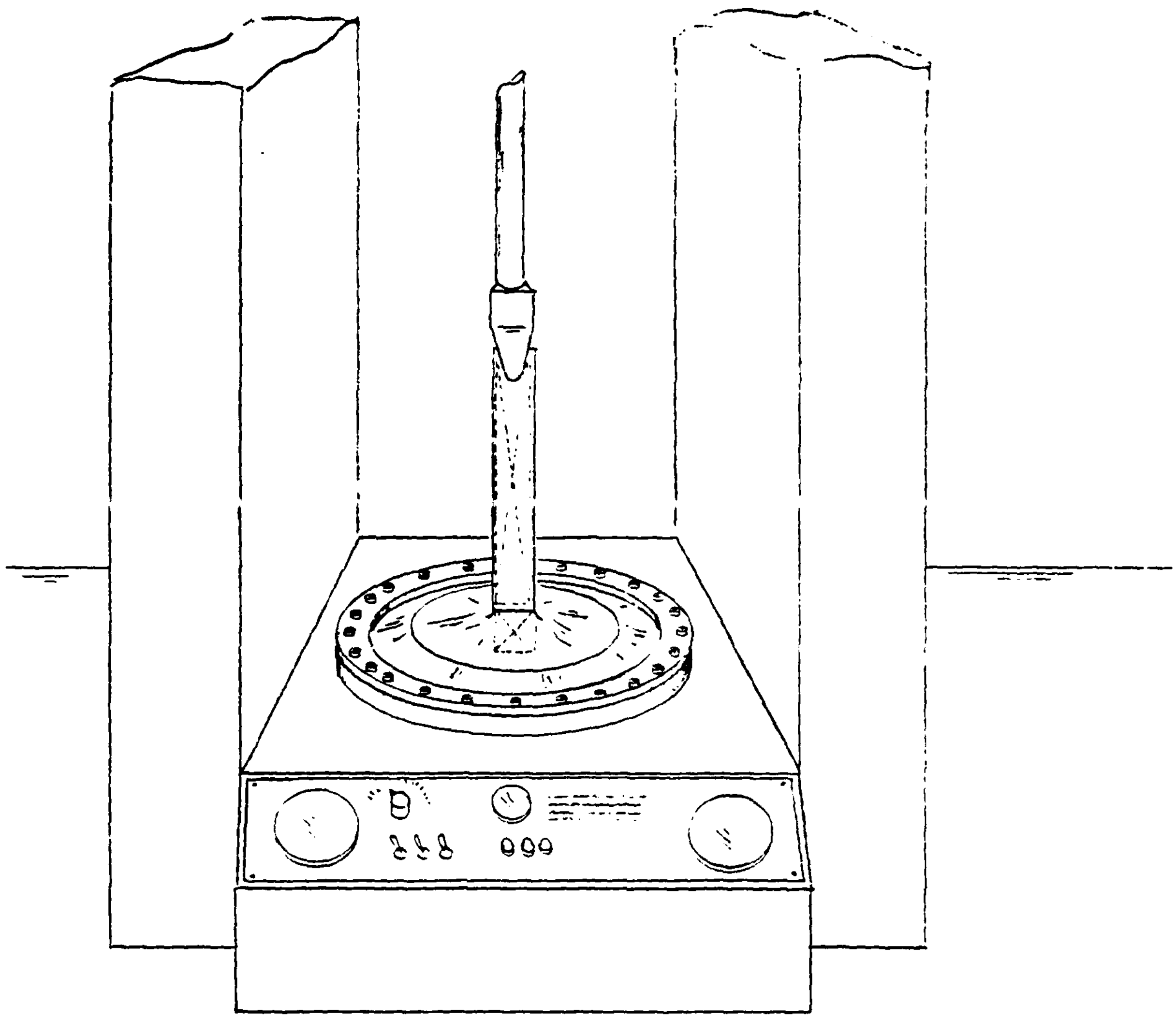

FIGURE 1 HANDLE PULL TEST FIXTURE

TABLE 17 TABER ABRADER TEST RESULTS

FABRIC	WEIGHT BEFORE (GMS)	WEIGHT AFTER (GMS)	WEIGHT LOSS (GMS)
1. V84-8-1 Estane 5708 on 8 oz. Nylon	12.55450	12.52710	.02740
2. V84-29-1 Estane 5714 on 8 oz. Nylon	15.69050	15.65085	.03965
3. 2391A Polysulfide/nitrile on 13 oz. Polyester	17.80030	16.45625	1.34405
4. 2391B Polysulfide/nitrile on 8 oz. Nylon	16.30950	15.28500	1.02450

It can be clearly seen that the polyurethane fared much better than the polysulfide/nitrile compounds. It can also be seen that, given the severity of the test, the coated fabric could be effectively used as a chafing patch.

The chafing patches will be bonded to the inside and the outside of the tank opposite each fitting. The patches opposite the vent assembly and the drain assembly will each be one and a half feet in diameter. The chafing patches opposite the filler and discharge assemblies will be two feet by three feet square with rounded edges.

2.2.4 FITTINGS

Investigation of commercially available hardware indicated that dimensionally, all required hardware (with the exception of the aluminum chest, per MIL-C-23044) was available commercially. The only problem with some hardware is the long lead time for delivery. A parts list is shown in Table18 delineating the manufacturer; the manufacturers address is shown in Appendix A.

A consideration that merited further study was whether or not the commercial compression fittings were strong enough to allow their use in this tank. *If a circular beam with a rectangular cross-section* is assumed, the following formula applies:

$$S_m = \frac{Mh_i}{A_e R_i} + \frac{P}{A} \qquad (1)$$

where S_m = maximum stress, psi.

M = bending moment, lb-in.

A = cross sectional area of beam, in^2.

R_i = inside radius of beam, in.

$$e = \frac{Z\,R_o}{Z+1}$$

where R_o = outside radius of the beam

$$Z = -1 + \frac{Ro}{h}\left(\ln \frac{Ro + C}{Ro - C}\right)$$

wnere h = width of beam

c = .5h

P = load on ring

The bending moment in this case is given by the following equation and it is assumed that there is a 100 pound per inch stress in the fabric (25% of the tensile of the fabric).

$$M = \frac{WL}{12} \qquad (2)$$

where W = total load on half the ring, lbs. 800 lbs.
L = given half the length of the ring, 8 in.(L=16 in.)
M = 533.3 lb./in.

Using the dimension from the commercially available option, the following values are used in equation 1

R_i = 5 in.
C = .75 in.
h = 1.5 in.
R_o = 6.5 in.
Z = 4.47×10^{-3}
e = .028949
A = .51
P = 800 lbs.
h_i = 1.47

$$S_m = \frac{(533.3)\ (1.47)}{(.51)(.029)(5)} + \frac{800}{.51}$$

$$S_m = 10,601 + 1569 = 12,170 \text{ psi}$$

The hardware is made of A13 aluminum which had a yield strength of 19,000 psi. This was more than adequate and provided a safety factor of 1.56. It was determined that the commercially available option is adequate and advantageous to use. A problem for past fittings has been fuel wicking through the threads of bolts going through the suction stub. ILC has designed a new suction stub to alleviate this problem. This will be included in all production tanks.

TABLE 18 HARDWARE PARTS LIST

I. FILLER/DISCHARGE ASSEMBLY

PART	PART NUMBER	MANUFACTURER
Access Door Fitting Compression Type	13X19-1 13X19-2	Cast-Rite
Suction Stub		ILC
MS9021-383, "O" Ring, Fluorosilicone		DBR Distributing
Oval Closure Plate	1836	Cast-Rite
Gasket, Fluorosilicone		SAS Gasket Supply
MS27023-17, Coupling Half Flanged		Evertite
Elbow, Female to Male 4"	81718/653-KB	OPW
MS27028-17 Dust Cap		Evertite
MS90725-61, Hex Head Cap Screw, .375-16		Century Fastener
MS90725-8, Hex Head Cap Screw, .25-20		Century Fastener
MS27183-10, Flat Round Washer		Century Fastener
MS35335-46, Lock Washer		Century Fastener
MS51967-8 Hex Nut		Century Fastener
Elbow, Female to Female, 4"	81718/633-KB	OPW
MS27030-9 Gasket, Fluorosilicone		Unirubber

II. DRAIN FITTING ASSEMBLY

PART	PART NUMBER	MANUFACTURER
Vent and Drain Fitting Compression Type	600-8-3 600-8-4	Cast-Rite
Drain Fitting	X1184	Cast-Rite
Plug and Chain		ILC
MS29513-250,"O" Ring Gasket ,Fluorosilicone		Unirubber
MS90725-7, Hex Head Cap Screw, .25-20		Century Fastener
MS27183-10, Flat Washer		Century Fastener

III. VENT FITTING ASSEMBLY

PART	PART NUMBER	MANUFACTURER
Vent and Drain Fitting Compression Type		Cast-Rite
MS29513-250, "O" Ring Gasket , Fluorosilicne		DBR
MS27183-10, Flat Washer		Century Fastener
MS90725- 7, Hex Head Cap Screw		Century Fastener
MS27023-21, Coupling, Male		ILC
MS27024-11 Coupling, Female		Evertite
MS27028-11, Dust Cap		Evertite
Pipe		ILC
Flame Arrestor and Relief Cap with Gasket	EX1333-2	Protecto-Seal
MS27030-6, Gasket Fluorosilicone		Unirubber

PART	PART NUMBER	MANUFACTURER
IV. ACCESSORIES		
8 ft. length hose (MIL-H-370, Type I)		Continental Rubber
1/2 inch rising stem gate valve (WW-V-54, Type 11, Class A)		Speakman
10 Ft. length hose (MIL-H-370, Type II, Size 9, Class 1, Style A)		Continental Rubber
Flanged Gate Valve with Flanged Gaskets, MIL-U-58039)	#676FR	OPW
MS27023-17 Coupling		Evertite
MS27027-17 Coupling		Evertite
MS27028-17 Cap		Evertite
MS27029-17 Plug		Evertite
Ground Cloth		ILC
V. EMERGENCY REPAIR ITEMS		
Repair Kit and Repair Kit Components		P.M Manufacturing Bogert and Hopper, ILC
O-Ring, MS 9021-383		DBR
O-Ring, MS 29513-250		DBR
Gasket, quick-disconnect coupling, MS 27030-6		Unirubber
Gasket, quick-disconnect coupling, MS 27030-9		"
Gasket, 4-inch flange		"

2.2.5 EMERGENCY REPAIR PROCEDURES

ILC has determined that any of the adhesives used in Table 16 can be used for repair of the Arctic fuel tank. The repair should be done at temperatures above 0^{o}F. A test was conducted between -30^{o}F. and -50^{o}F. to determine if the adhesive could be used for repair in open Arctic conditions. Two adhesives, the Shore UR1087 and UR1092, froze solid at this temperature. The Bostic 7133 and the B.F. Goodrich A1246B were still in a liquid state (due to THF content of each). The drying times required in application of these adhesives was quadrupled. When the two pieces of material were put together, the load was very weak. For holes and tears at Arctic temperatures, the current plugs and clamps should be used unless some kind of heat and pressure can be applied to the area in question. Once the tank is brought above 0^{o}F, the plugs or clamps could be removed and a patch applied.

Because they display excellent cold temperature properties and ease of application, ILC recommends that for repair of the Arctic Fuel Tank, B.F. Goodrich A1246B or Bostick 7133 be used. Care should be taken in the application of these adhesives. The THF content emits toxic fumes, thus use in a well ventilated area or with a gas mask is suggested.

Upon completion of fabrication of the first prototype tanks, an emergency repair procedure will be included in the technical manual.

ILC has determined that there is no real need to ground the tank. However, a static wire will be attached to the drain assembly to provide this option.

2.2.6 STATIC ELECTRICITY CONSIDERATIONS

ILC has studied several different options for control of static electricity. Currently, during filling and discharge of the tanks, only a static wire is used in grounding the pump.

There are several options available that are currently feasible but have a significant cost impact. One method consists of including silver coated nylon yarns in the base fabric. This is currently done by Sauquot Industries. This causes about a 1.5% weight increase and about a 100% increase in the cost of the base fabric. Another method consists of impregnating metal flakes in the coating elastomer. This approach is currently used in piping, tubing, wheels, rollers, conveyor belts, and sensitive instrumentation. One manufacturer who has done this extensively is Transmet Corporation. This will increase the cost of the coated fabric by about 65%.

One technique which points out another advantage of polyurethane over nitrile rubber is that urethanes are less likely to retain the static electricity. The Air Force has stated that urethanes have a lower resistivity to conductivity than nitriles. Therefore, for fuel tank bladders currently in use in the structures inside Air Force airplanes, the requirement for static wires to ground the bladders has been deleted.

The approach recommended by ILC is an anti-static spray or coating. One spray, manufactured by Analytical Chemical Laboratories, can be applied either in the field or at the factory and is inexpensive. It is currently used to coat the metal fuel tanks of the Trident missile and can last up to a year in outdoor conditions. Reeves Brothers makes an anti-static coating that can be brushed on. This coating is the better of the two compounds and one gallon will be supplied with the four prototype 3000 gallon tanks.

2.2.7 TANK DESIGN

The tank design will be finalized and four tanks fabricated from this design. That design will be delineated in the Phase II Final Report.

2.3 RECOMMENDATIONS

ILC recommends that two 3,000 gallon tanks of each candidate material be fabricated. These tanks should be fabricated with a Tuftane 310 S-Type between the seams. The handles should be fabricated as ILC has designed. The chafing patches should be located and fabricated as in paragraph 2.2.3. The fittings for these tanks should be the commercially available hardware listed in Table 18.

An emergency repair procedure and a final report manual will be written and provided upon completion of the fuel tanks. Anti-static agent should be acquired and coated on at least one tank. A hand held static locator should also be purchased and readings taken on the treated versus non-treated tank.

APPENDIX A

LIST OF SUPPLIERS

Uniroyal Textile Division
350 Columbia Rd
Winnsboro, South Carolina

J. P. Stevens
1185 Avenue of the Americas
New York, New York

Burlington Industrial Fabrics
Link Drive
Rockleigh, New Jersey

Dow Chemicals
2040 Dow Center
Midland, Michigan

Thiotol Chemical Division
P.O. Box 8296-T
Trenton, N.J.

B.F. Goodrich
6100 Oak Tree Boulevard
Cleveland, Ohio

DuPont
Wilmington, Delaware

Beatrice Foods
Permuthane Division
Peabody, Mass.

Speakman
42 Salisbury Rd.
Dover, Del. 19901

Continental Rubber
2000 Liberty St.
Erie, Pa. 16512

Bostik Division - USM Corp.
Boston St.
Middleton, MA 01949

Hughson Chemicals
2000 W. Grandview Blvd.
Erie, Pa. 16512

Century Fastener
50-20 Ireland St.
Elmhurst, N.J. 11379

Astrux Co.
2937 W. 25th. St.
Cleveland, Ohio 44113

DBR Distributing Co.
83 North Main St.
Yardley, Pa. 19067

MSA
36 Great Valley Parkway
Malvera, Pa. 19355

SAS Gasket and Supply Co.
275 Adams Blvd.
Farmingdale, N.Y. 11735

Protecto Seal Co.
227 Foster Ave.
Bensenville, Ill. 60106

PM Manufacturing
P.O. Box K
Eaton Park, Fla. 33840

Bogert & Hopper, Inc.
23 W. John St.
Hicksville, N.Y. 11801

OPW
9393 Princeton Glendale Rd
P.O. Box 40240
Cincinnati, Ohio 45240

Evertite
254 W. 54th.
N.Y., N.Y. 10019

Cast-Rite Corp.
515 East Airline Way
Gardena, Ca. 90248

Norton Co.
P.O. Box 70729
Charleston, S. C. 29405

Analytical Chemical Labs
1960 E. Devon Ave.
Elk Grove, IL 60007

Unirubber, Inc.
130 A East 35th. St.
New York, N.Y. 10015

APPENDIX B

ELASTOMER FORMULATIONS

Polysulfide/Nitrile Compound (2391A, 2391B)

[1]Thiokol ST	75.0
[3]Hycar 1094	25.0
Stearic Acid	1.0
[4]Sterling NS x 76	60.0
Zinc Peroxide	5.0
Calcium Hydroxide	1.0
[1]TP - 90B	20.0
Agerite Stalite	0.25

Polysulfide/Neoprene Compound (2363A, 2363B)

[1]Thiokol ST	75.0
[2]Neoprene WRT	25.0
Stearic Acid	1.0
Sterling NS x 76	50.0
Zinc Peroxide	5.0
Calcium Hydroxide	1.0
[1]TP - 90B	20.0
Agerite Stabilite	0.25
[6]Scorchguard O	1.0
[7]C-2944	0.125

Fluorosilicone Compound (2361A, 2361B)

[10]LS-63-U	100
Red Iron Oxide	1

Polyurethane Compounds (V84-26-1, V84-8-1, V84-29-1, V84-31-1, V84-30-1, V84-32-1)

Polymer	100
Sterling NS x 76	2
[8]Vinyzene BP-5	2
[9]Staboxol P	2

1. Thiokol Chemical Co.
2. DuPont
3. BFG Chemical Co.
4. Cabot
5. Vanderbilt
6. Wyrough & Loser
7. Ware Chemical
8. Scientific Chemical
9. Mobay Chemical
10. Dow Corning
11. Harwick